COHERENT LASER RADAR METROLOGY SYSTEM FOR LARGE SCALE OPTICAL SYSTEMS

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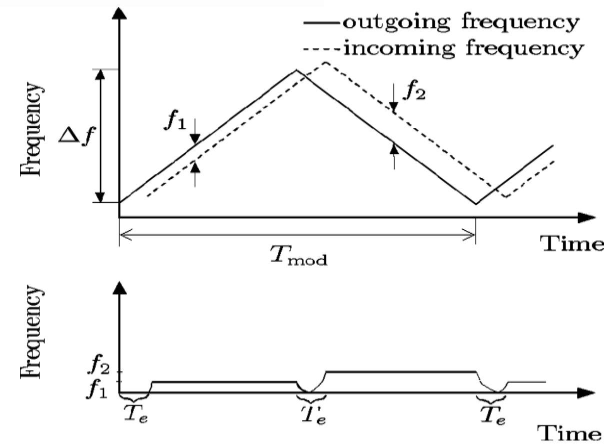
Coherent Laser Radar Metrology System for Large Scale Optical Systems
Pyxisvision Incorporated, Bristow, VA

Identification and Significance of Innovation

A new type of laser radar metrology inspection system that incorporates a novel, dual laser coherent detection scheme capable of eliminating both environmental and scanner based Doppler ranging error has been shown to be feasible. Due to the non-contact, stand-off nature of this technology, this system can measure optics and provide nearly real-time feedback to figuring/polishing instruments and, for advanced levels of integration and test, would allow fast, non-contact measurement of mirror rigid body alignment and prescription (i.e., radius, conic, aperture), with no special targets or references on the optic.

Estimated TRL (1 – 9) at beginning and end of contract: Beginning: 4, End: 6



Technical Objectives and Work Plan

Develop and fabricate the components for a prototype measurement system with:

-An Instantaneous Doppler Correction (IDC) dual laser oven for up to 100x improved range accuracy

-A Post-scanner Lens for up to 10x increase in scanning angular accuracy

-Improved target detection algorithms

The work plan has the following tasks:

-Fabricate and test a prototype IDC dual laser ranging device

-Develop a post-scanner lens with a calibration model to increase scanning accuracy

-Develop the embedded, signal processing and Windows interface software to support edge and hole detection algorithms.

NASA and Non-NASA Applications

-Joint Dark Energy Mission (JDEM) telescope mirror fabrication and integration

-International X-ray Observatory (IXO) x-ray telescope mirror prescription and alignment measurement

-mm-wave antenna fabrication and assembly

-Aircraft and ship-building industry support

-Optical telescope assembly

-Optical instrument assembly

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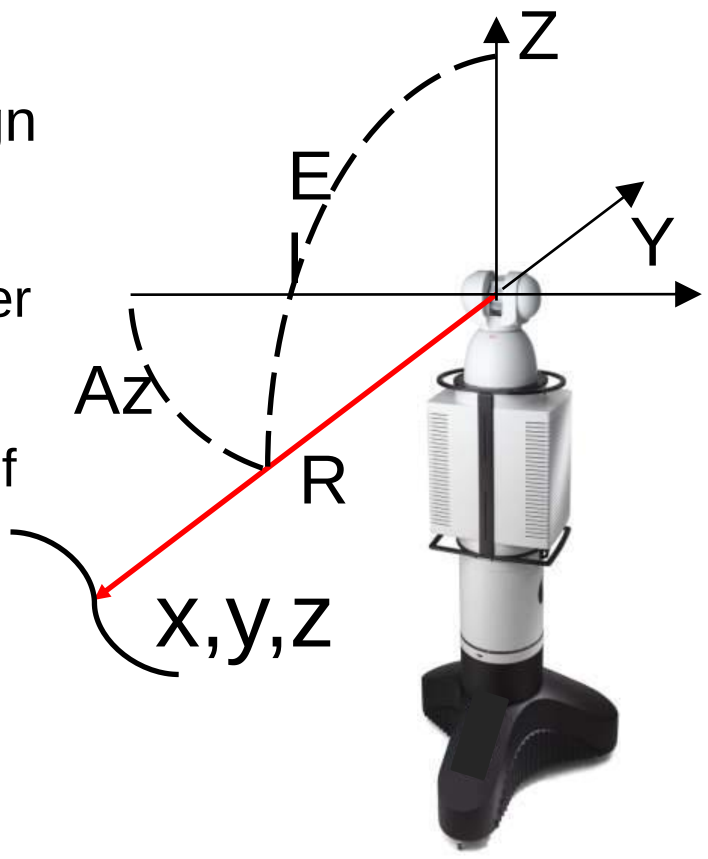
NON-PROPRIETARY DATA

Innovation Objective

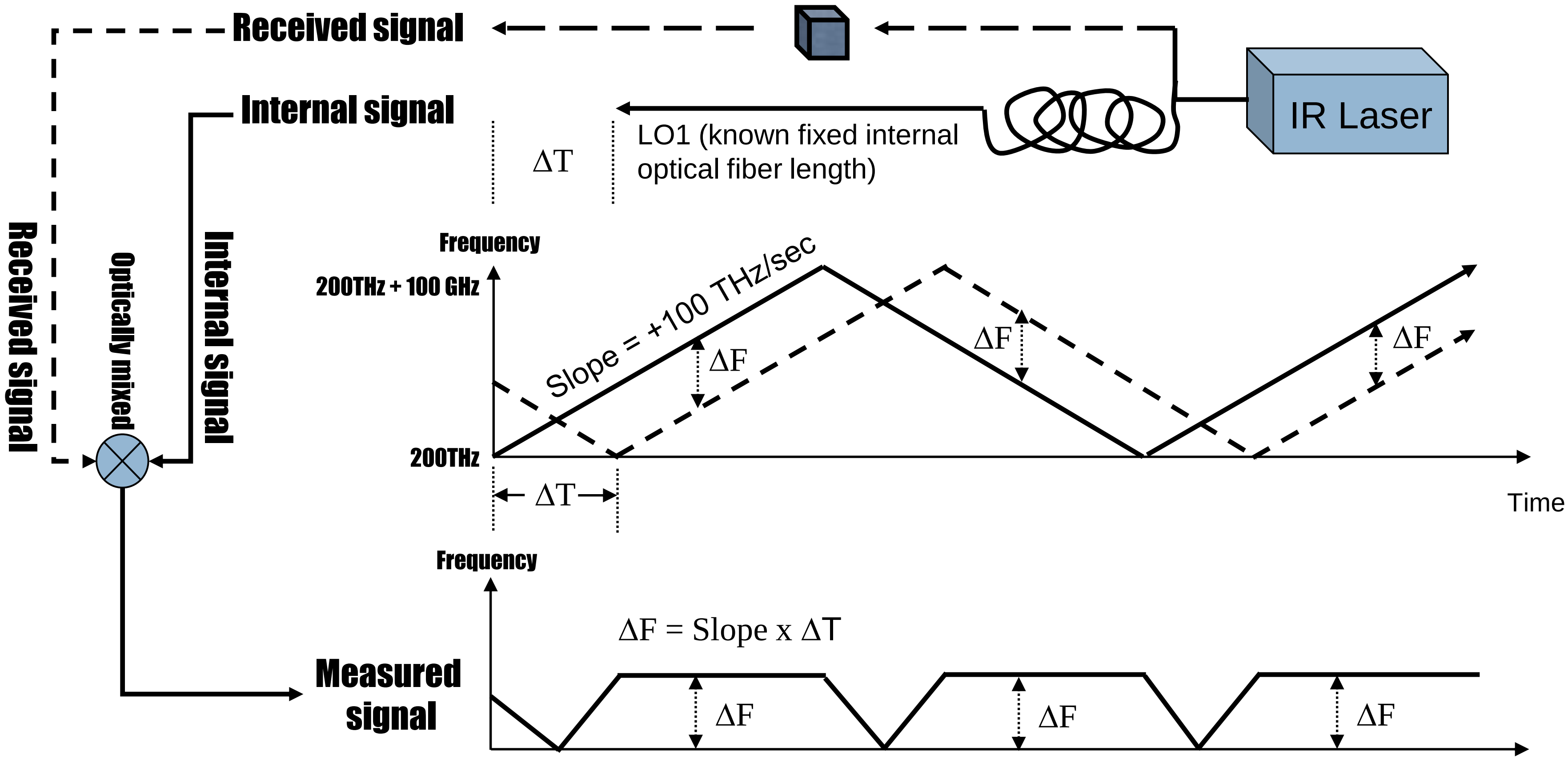
- Measurement of large telescope structures and optics requires both high accuracy and non-contact technology. The significance of these innovations is to provide a metrology system that is:
  - Able to characterize optics without removing the part from its location and at a large stand-off distance.
  - Capable of micron ranging accuracies.
  - Able to, through the development of telescope mirror edge/aperture detection algorithms, accurately measure mirror edges for both segmented and monolithic aperture systems.
  - Capable of making large mirror prescription measurements from long distances at essentially all stages of mirror fabrication, integration and test.

Technical Objective

- The specific technical objective of Phase 1 effort was to develop a prototype measurement system design with the characteristics as follows:
  - By means of a novel, dual laser configuration, improvement of the Laser Radar ranging accuracy.
  - By means of a new scanner design, increase the angle pointing accuracy of the Laser Radar by a factor of ten.
  - By means of software development, producing better target detection algorithms including:
    - Improved edge detection repeatability.
    - Improved hole measurement algorithm.



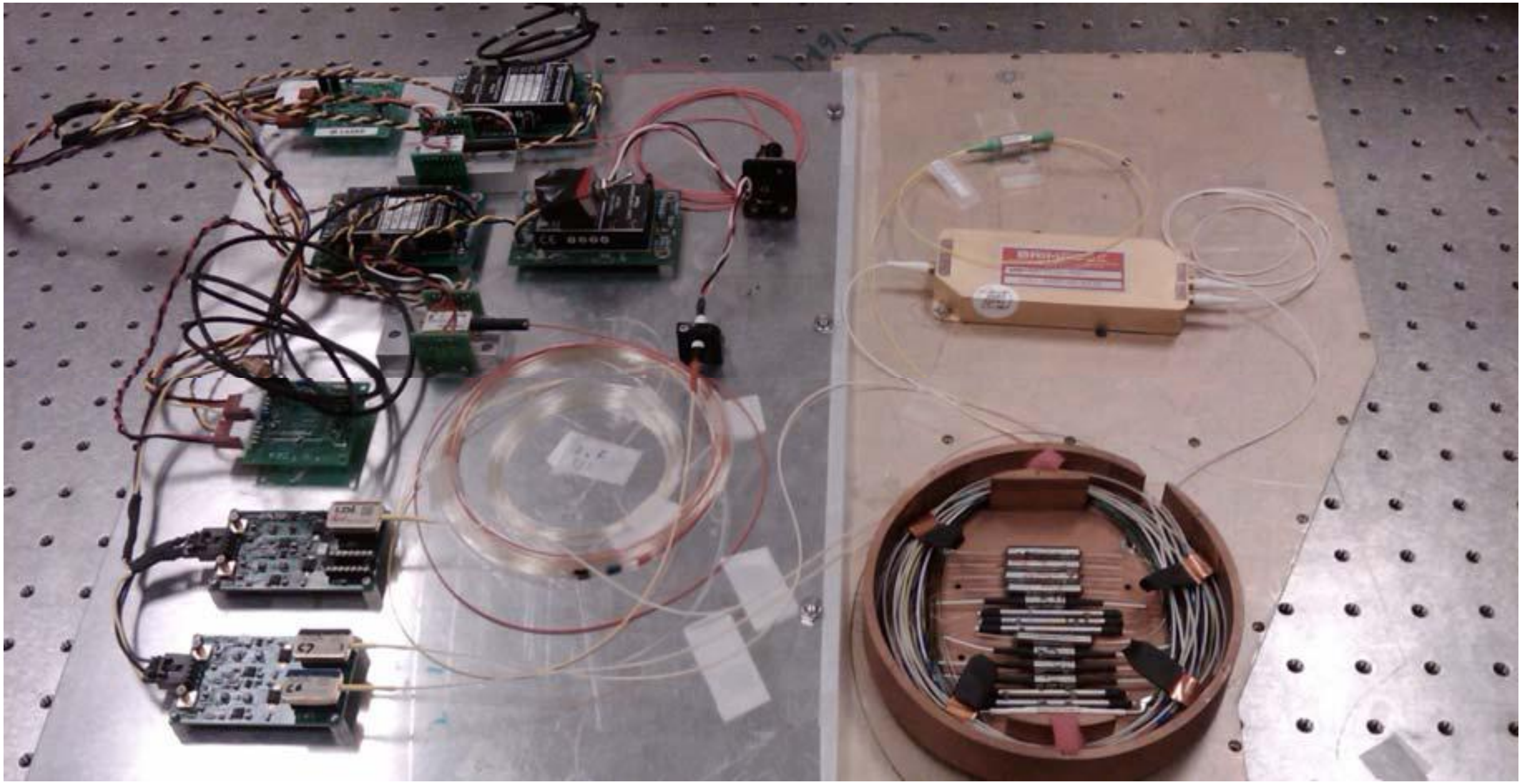
FM CLR Basic Principles



- ΔT is difficult to measure
- BUT ΔF can be measured very accurately and with a known "Slope" we can calculate ΔT !

IDC oven Prototype

Dual laser radar IDC oven prototype hardware.



IDC oven Prototype

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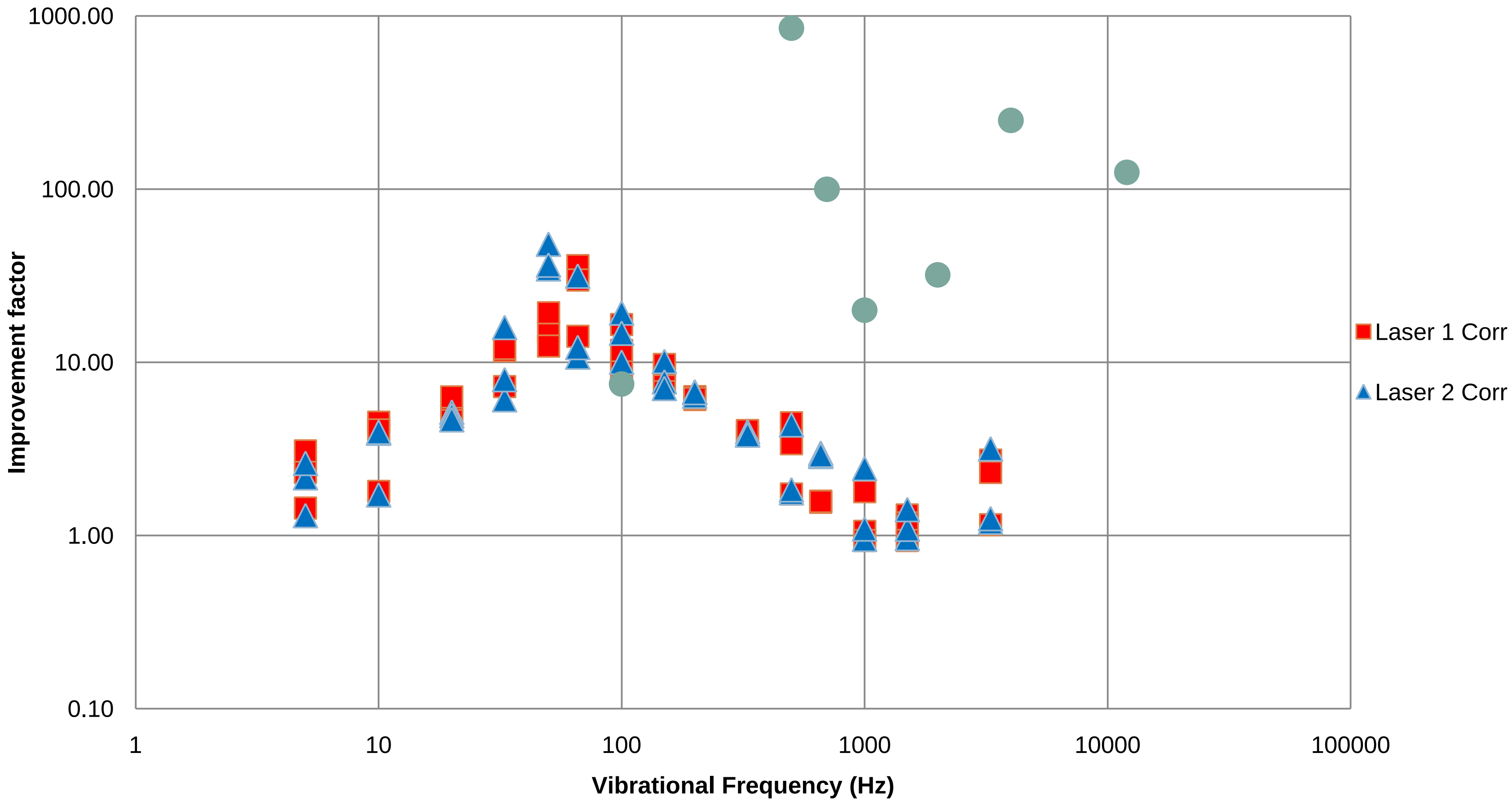
Correction summary vs. oven configuration tested

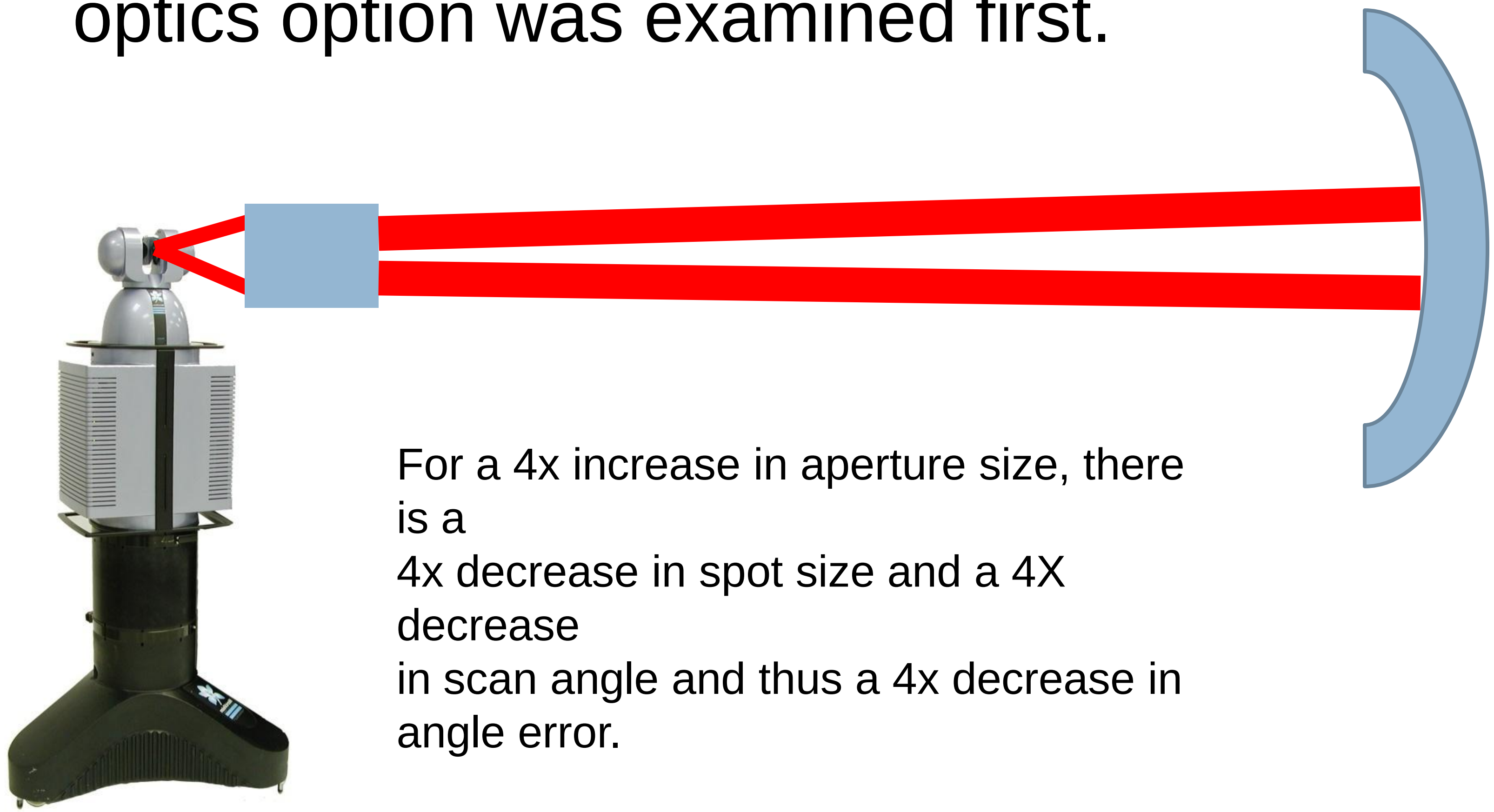


Future Development

- In the next phase of this program, the IDC laser radar will be developed including:
  - Fabrication of the optical and electro-optical portion of the radar
  - Development of the signal processing signal chain
  - Updating of the electronics to support the optical input channels in real time.

Ultra Accurate Positioning

- Due to its advantages, the post scanning optics option was examined first.



For a 4x increase in aperture size, there is a
4x decrease in spot size and a 4X decrease
in scan angle and thus a 4x decrease in angle error.

Ultra Accurate Positioning

- Development of a post scanning optical solution to improve the positional accuracy
  - Viewing parameters were determined
  - Parameters and specifications of the optics were developed.
  - Completed the determination of the parameters and specifications of the optical assembly.
  - Specifications were sent to various optical fabricators for quotes
- Other hardware options were examined to determine if a larger aperture system is feasible by other means.

Future Development

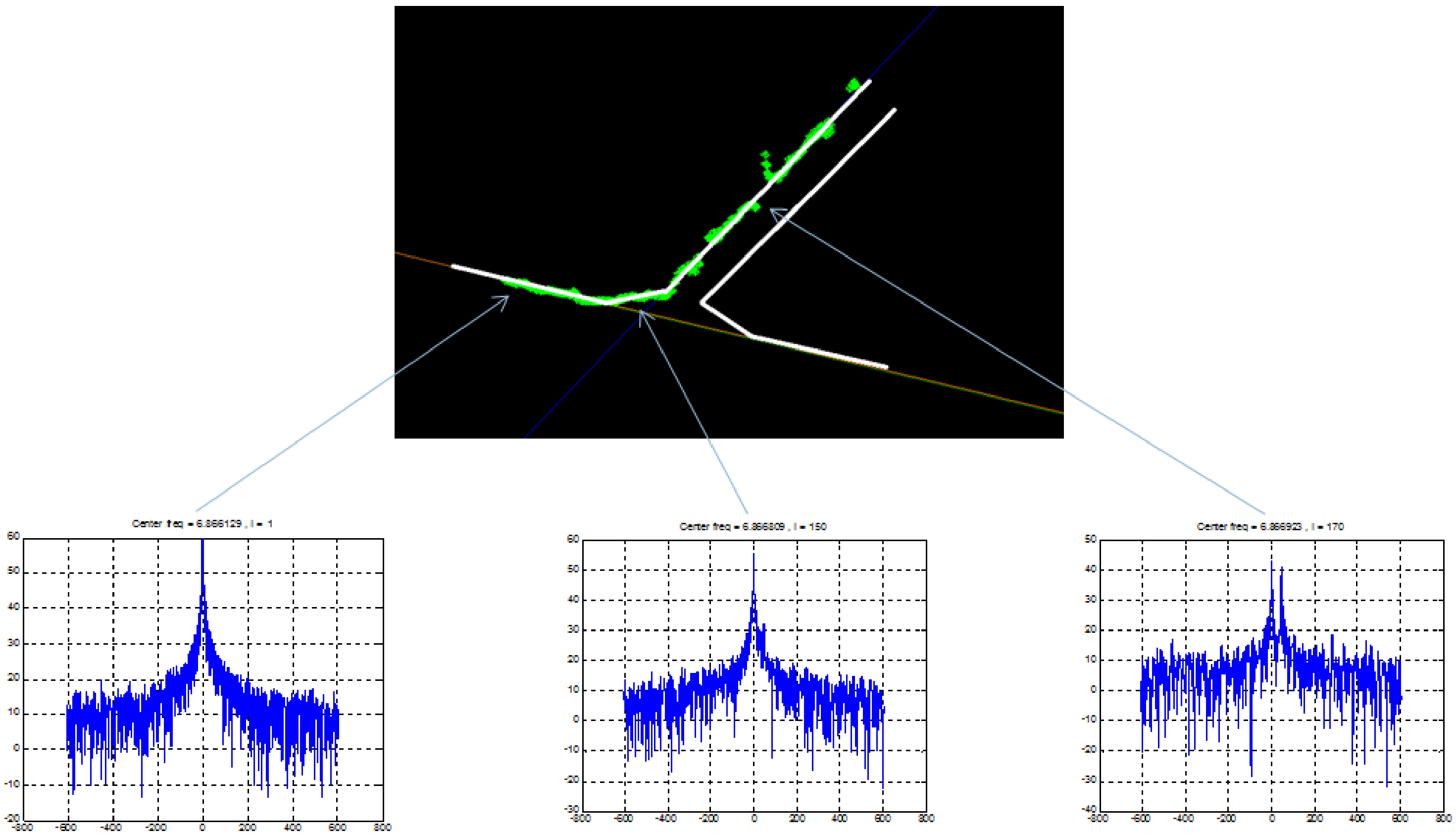
- In the next phase of this program, the hardware for the ultra accurate positioning assembly will be fabricated and integrated into a laser radar system.
  - Procurement of the fabrication of the post scanning lens.
  - Design of the lens-to-laser radar mounting hardware.
  - Integration of the lens with laser radar.
  - Development of the lens calibration model.
  - Lens and model performance verification.

Algorithm development

- Developed new software to collect raw FFT, sweep and angle data on optical surfaces provided by NASA
- New embedded and DSP software was written to support this effort. The data was processed and analyzed using Matlab.
- Developed a new FFT peak picker algorithm to correct for multiple reflections.
- Development of a new edge algorithm that tracks the FFT peak and the correlation of the beam and the surface in Matlab was also started
- Investigated the embedded software architecture to determine if multiple peak data processing and real time edge algorithms and reflection issues can be supported in the current architecture and electronics

Algorithm development

FFT shape over an edge



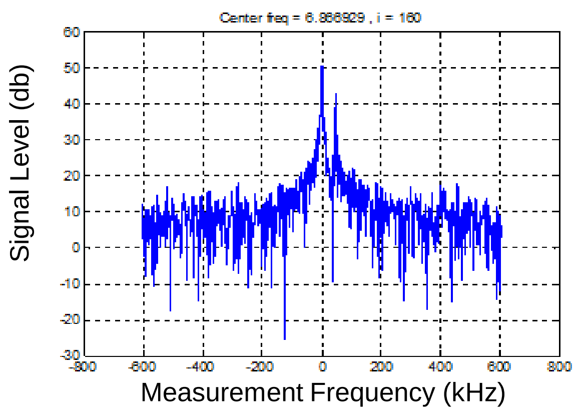
Surface FFT no multi peaks

FFT with beam hitting edge

FFT with beam reflecting of adjacent edge wall

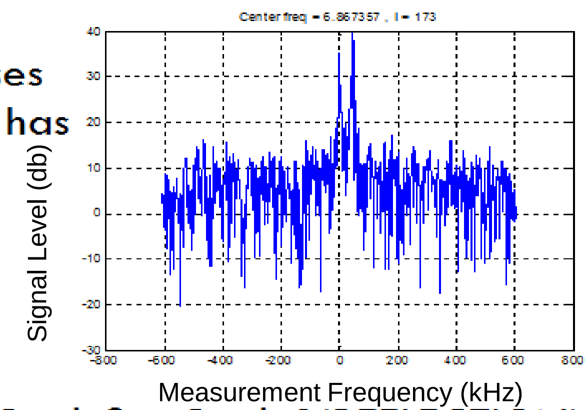
Algorithm development

Current architecture returns one peak only (highest peak).

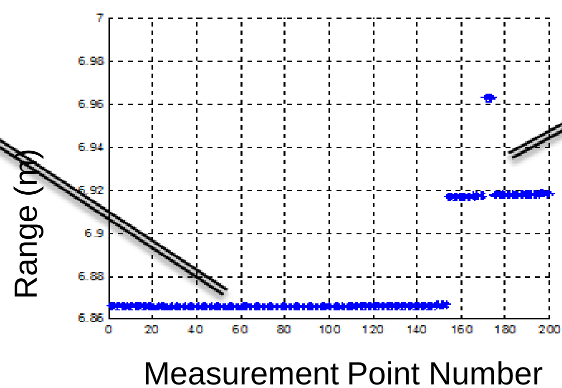


Peak 1 > Peak 2

Current Algorithm Reflection Data causes Un usable data that has wrong range.



Peak 2 > Peak 1 (REFLECTION)



Algorithm development

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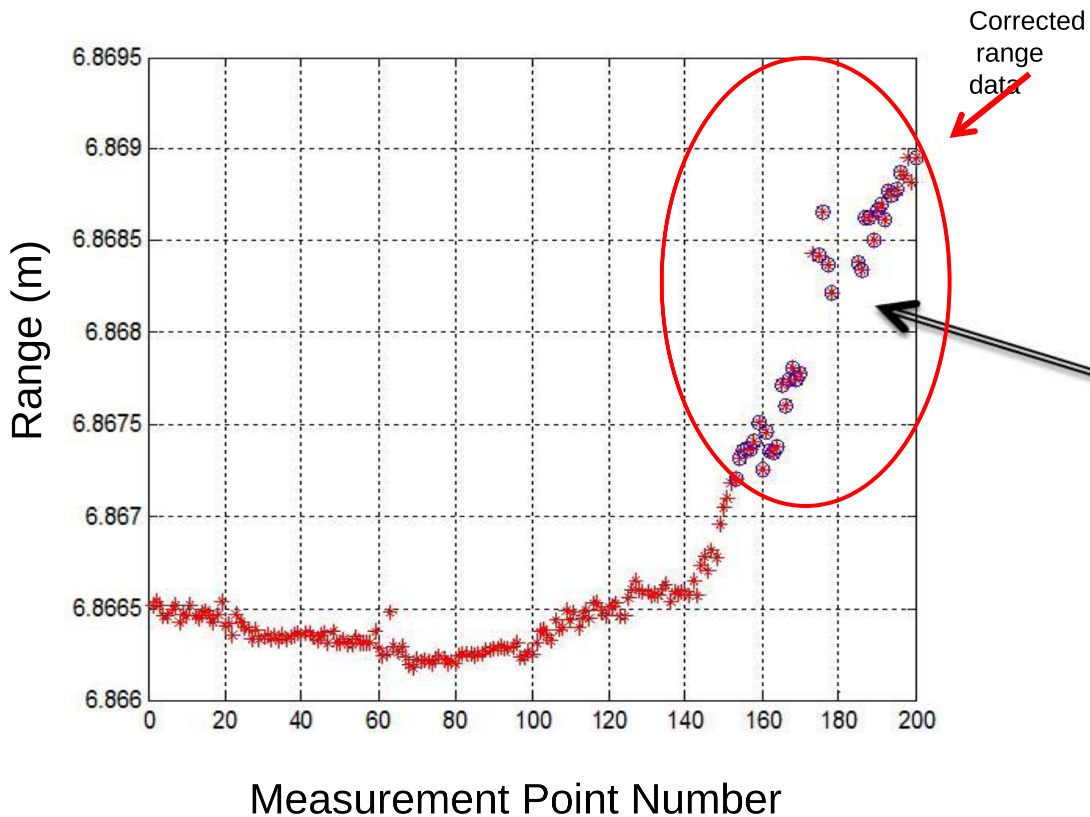
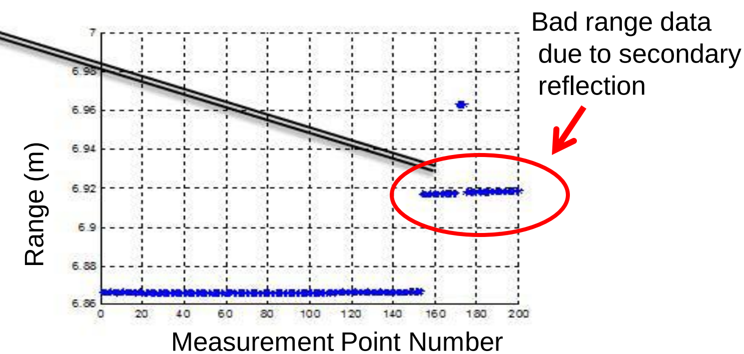
New peak picker algorithm for reflection



Same data from previous figure with new algorithm shows reflection correction for range measurements for an edge scan.



Future Development

- In the next phase of this program, new software architecture will be developed to support multi peak buffering and processing in real time.
  - Embedded software architecture redesign in QNX OS written in C++.
  - Algorithm development on embedded software and on DSP.
  - Windows interface software development.

SBIR Phase II Schedule

Task	Task Description	Q3 2011	Q4 2011	Q1 2012	Q2 2012	Q3 2012	Q4 2012	Q1 2013
Task 1	***Develop a dual laser oven to correct for Doppler***							
Subtask 1	Optical development	x	x	x	x			
Subtask 2	Signal processing development		x	x	x	x		
Subtask 3	Electronics development			x	x	x	x	x
Task 2	***Development of ultra accurate position mirror assembly.***							
Subtask 1	Lens development.		x	x	x			
Subtask 2	Lens mounting hardware.			x	x	x		
Subtask 3	Lens integration.				x	x	x	
Subtask 4	Calibration model development.					x	x	x
Subtask 5	Performance Verification.						x	x
Task 3	***Software and Algorithm Developments***							
Subtask 1	Embedded software architecture redesign in QNX OS written in C++.	x	x	x	x			
Subtask 2	Algorithm development on embedded software and on DSP.			x	x	x	x	
Subtask 3	Windows Interface Software Development				x	x	x	x